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Assessment of Analyses Performed for the California Energy Efficiency Regulations for Consumer Electronics Products

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1. Introduction

California has adopted new energy efficiency standards for a wide range of products, including televisions (TVs), digital versatile disk (DVD) players and recorders, compact audio products, digital television adapters (DTAs), and external power supplies (EPS; see Table 1-1).

Table 1-1: California Energy Efficiency Standards (from CEC 2005)

Product		Standby / No-Load Power [W]	Active Mode Power / Efficiency
Televisions		3	N/A
Compact Audio		2[1]	N/A
DVD Players and Recorders		3	N/A
Digital Television Adaptors (DTAs)		1	8W
External Power Supplies (EPSs)	Tier 1	<10W: 0.5W 10+W: 0.75W	<1W: 0.49*Nameplate Output 1-49W: 0.09*ln(Nameplate Ouput) + 0.49 >49W: 0.84
	Tier 2	0.5W	<1W: 0.5*Nameplate Output 1-51W: 0.09*ln(Nameplate Ouput) + 0.5 >51W: 0.85

The Consumer Electronics Association tasked TIAX to perform an independent assessment of the analyses used by the California Energy Commissioning (CEC) to determine the cost-effectiveness of the standards for the aforementioned consumer electronics devices, i.e., Fernstrom (2004a) and Fernstrom (2004b). These analyses are crucial for establishing effective standards levels for products, as a standard must have a positive life-cycle cost to be enacted.

This report presents the TIAX assessment and its key findings.

1.1. Methodology

The cost-effectiveness of a standard level depends on the net-present value (NPV) of the standard over the average lifetime, *life*, of the product in question. The NPV equals the sum of the discounted cost of energy saved over the average product lifetime[2] less the incremental cost to the end-user for a typical new non-compliant product, *dCost*, to

[1] 4W for units with a permanently illuminated clock display.
[2] Ideally, such an analysis takes into account differences in maintenance costs. For this analysis, it was assumed that the new standards did not increase or decrease per-unit maintenance costs over the effective product lifetimes.

satisfy the regulation (section 2.1 summarizes the NPV calculation approach). In this case, the non-compliant and compliant products should only differ in ways related to their power draw characteristics, i.e., they should have the same features.

$$NPV = \sum_{year=1}^{life} NPV_{year} - dCost$$

In turn, the annual energy savings, E_{save} depends on the product of the annual operational hours in the number of modes, n, impacted by the regulation, h_{mod}, and the difference between the typical power draw in that mode between a typical new non-compliant product, p_{nc}, and a compliant product, p_c.

$$E_{save} = \sum_{\mathrm{mod}=1}^{n} h_{\mathrm{mod}} \cdot (p_{nc} - p_c)$$

Performing the calculations with typical new products instead of products typical of the installed base provides a clearer picture of the energy savings and economic impact of the regulations because it calculates the savings relative to the products that would likely be sold without the regulation. A more sophisticated analysis might attempt to develop a moving baseline for products' performance by projecting the power draw and usage characteristics of "typical new" products out into the future to take into account changes in product technology, features, and usage. For many consumer electronics products, however, this could be very challenging due to the rapid rate of change. Consequently, this analysis assumes that the "typical new" product does not change appreciably.

2. Evaluation of the Data Used to Assess the Cost-Effectiveness of the California Consumer Electronics Energy-Efficiency Standards

This section assesses the key parameters used in the cost-effectiveness analyses for the consumer electronics products impacted by the energy-efficiency standards. Section 2.1 succinctly studies the financial parameters. Section 2.2 evaluates the parameters used in the analyses for televisions, compact audio products, DVD players and recorders, and digital television adapters, while Section 2.3 assesses the analysis of EPSs used to power many consumer electronics devices.

2.1. Financial Parameters

2.1.1. Discount Rate

The CEC use a real discount rate of 3% for future electricity savings (CEC 2004). This is substantially lower than the rates used in analyses used in two recent U.S. Department of Energy residential appliance and equipment rulemakings. Specifically, the ongoing residential furnaces and boilers rulemaking uses a weighted "after-tax real interest or return rate" based on a mix of household debt and equity of 6.7%[3] (DOE 2005), while the residential central AC and heat pump rule that took effect 23 January, 2006 used a discount rate of 7% (DOE 2001). Much of the difference arises because the CEC primarily derives interest rates from loans while the DOE considers a broader range of investments. Consequently, TIAX believes that a real discount rate similar to that used in the DOE analyses, i.e., around 7%, would be more appropriate for the current analysis. Results are presented for both discount rates.

2.1.2. Electricity Price

The CEC uses an average electric price of $0.115/kWh in the tables for the consumer electronics and external power supplies (Tables 20A and 20B, from CEC 2004). The current analysis uses the same cost of electricity and uses the same net-present value (NPV) methodology outlined in CEC (2004) to discount future energy savings over the average lifetime of the device:

$$NPV_{year} = \frac{1}{(1+DR)^n} \quad \begin{matrix} if\ year = 1, n = 0 \\ else\ n = year \end{matrix}$$

DR denotes the real after-tax discount rate and "*year*" the year of the analysis.

[3] Assumes a 28% marginal income tax rate and 1.56 percent price inflation.

2.2. Consumer Electronics

2.2.1. Televisions (TVs)

Table 2-1 compares the analysis used for the original cost-effectiveness assessment, Fernstrom (2004b), with the current re-analysis values.

Table 2-1: Energy-Related Television Characteristics

Characteristic	PG&E (2004b)	Initial Re-Analysis	Comments on Data
CA Installed Base [millions]	24.5	26.8	Not including TV combination units; exclusion of TVs with POD card slots would likely result in slightly lower values.
CA 2005 Shipments [millions]	2.5[4]	3.2	
Avg. Lifetime [yrs]	7	7	
Standby Usage [hrs/yr]	6205	7285	
Standby Power Draw [W]	7.3	3.9	Moderate uncertainty in power draw value for re-analysis; see below.
CEC Standard Standby Power Draw [W]	3	3	
Annual Energy Savings [kWh]	27	6.6	
Incremental Cost [$/unit]	$3	Unknown	High uncertainty in incremental cost
NPV of California Standard Over Product Lifetime [3%]	$16	Unknown	Would be $1.70 for a $3 incremental cost
NPV of California Standard Over Product Lifetime [7%]	$14	Unknown	Would be $1.10 for a $3 incremental cost
First Year GWh Savings	68	21	

2.2.1.1. Installed Base and Annual Shipments

California represents about 11% of the total US households (U.S. Census 2006[5]). To calculate the installed base of TVs in California, the number of California households was multiplied by an estimate of 2.4 TVs per household (from Ostendorp et al. 2005). Based on CEA (2005) sales estimates, TV combination units account for approximately 12% of the installed base of TVs; these units are excluded from the regulation and do not appear in the total presented. In addition, CEA (2005) reports sales of 30.6 million TVs in 2005, of which 6 percent were TV-VCR combination units. California's percentage of

[4] Units covered by the standard; TV-VCR Combination units (an additional 551,000 units) are not covered.
[5] Based on an extrapolation of number of households to 2005 using population growth data.

U.S. households yields an estimate that 3.2 million TVs impacted by the standard were sold in California in 2005.

2.2.1.2. Power Draw by Mode

The regulation only applies to the standby mode of televisions and the assessment focuses on that mode. Fernstrom (2004b) cites DOE (2002) as a source for standby power draw values used for the baseline energy consumption estimates (see Table 2-1) and applied the 7.3W value for analog TV value to all televisions. The DOE (2002) study relied upon data that are now several years old and appear to not reflect the standby mode power draw characteristics of current devices. Notably, digital TV unit sales exceeded the sale of analog TVs in 2005 for the first time (CEA 2005). The trend toward greater digital TV sales will almost certainly continue as the cost of digital TVs continues to decrease and the mandated transition to digital TV occurring in 2009 draws nearer.

About 22%[6] of televisions sold in 2004[7] met the 1W[8] standby (Tier 2) EnergyStar® criterion (Fanara 2005), while another 24% are estimated to have met the now-obsolete 3W standby criterion (Tier 1, CCAP 2005). Consequently, it appears that more than 40% of TVs sold in 2005 meet the CEC standby power draw standard. A recent study evaluating TV energy consumption estimated that the installed base of TVs had a median standby power draw of 3.9W[9] and that this did not vary appreciably with TV technology (Ostendorp et al. 2005). Given the more recent vintage of this report, TIAX recommends using this value for the preliminary economic and energy-savings analyses.

2.2.1.3. Annual Hours by Mode

Fernstrom (2004b) cites DOE (2002) for their estimate that the average TV spends 6,205 hours per year in standby mode. A more recent analysis of TV energy consumption estimates that the average TV spends between 6,935 and 7,285 hours in standby mode per year (based on 2000 census data; Ostendorp et al. 2005). In this case, the former value is for a household with a single TV, while 7,285 represents the value for an average TV in the U.S. (i.e., it assumes that usage for second, third, fourth, etc. TVs decreases). A separate TIAX calculation based on the methodology of Rosen and Meier (1999a) comes up with a similar value to 7,285, and TIAX recommends using this value for the analysis.

2.2.1.4. Incremental Cost to Meet the Regulation

Fernstrom (2004b) estimates that the incremental cost to achieve a 3W standby power draw for non-compliant TVs equals $3. The document notes that "incremental costs for

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[6] CCAP (2006) estimates this percentage at 20%.

[7] On 1 July, 2004, the maximum allowable power draw decreased from 3W for all single-function TVs to 1W for analog TVs and 3W for digital TVs. Effective 1 July, 2005, a 1W level came into effect for both analog and digital TVs (EnergyStar 2006a).

[8] The average power draw of the 854 TVs listed in the EnergyStar® database in January, 2006 equals 0.66W.

[9] Although they do not constitute a statistically-representative sample, measurements of 15 CRT TVs located in eight homes found an average standby power draw of 3.5W (Nordman and McMahon 2004).

most of the standby energy efficiency measures are difficult to quantify, but are expected to be very low," but provides no way to evaluate the validity of this statement. That is, the document does not provide a citation for the source of the estimates, nor does it lay out the design changes or design path applied to achieve 3W (or less) standby power draw. Thus, it is not possible to assess the validity of the estimated incremental cost.

To develop meaningful incremental cost estimates, TIAX recommends performing a design option analysis for televisions. This involves purchasing and dissecting multiple televisions with different energy performance (i.e., compliant and non-compliant) produced by different manufacturers to understand what components contribute to standby power draw. Based on this analysis, it can be determined what components manufacturers may add or modify to improve energy performance and how the components impact other aspects of the design. A meaningful estimate of the incremental cost can then be developed by creating a cost model that calculates the cost impact of any design changes in a corporation’s manufacturing context. The cost of compliance to the consumer can then be estimated by determining and applying typical markups associated with the product (see the discussion in Section 2.3.4).

2.2.2. Compact Audio

Table 2-2 compares the analysis used for the original cost-effectiveness assessment, Fernstrom (2004b), with the current re-analysis values.

Table 2-2: Energy-Related Compact Audio Characteristics

Characteristic	PG&E (2004b)	Current Analysis	Comments on Data
CA Installed Base [millions]	7.8	5.8	
CA 2005 Shipments [millions]	1.1	0.75	
Avg. Lifetime [yrs]	5	6	
Standby Usage [hrs/yr]	6570	6470	High uncertainty in standby usage values; see below.
Standby Power Draw [W]	9.8	3.0	High uncertainty in standby power draw values; see below.
CEC Standard Standby Power Draw [W]	2	2	
Annual Energy Savings [kWh]	51	6.5	
Incremental Cost	$1	Unknown	High uncertainty in incremental cost
NPV of California Standard Over Product Lifetime [3%]	$26	Unknown	Would be $3 for a $1 incremental cost
NPV of California Standard Over Product Lifetime [7%]	$24	Unknown	Would be $3[10] for a $1 incremental cost
First Year GWh Savings	56	5	

2.2.2.1. Installed Base and Annual Sales

Fernstrom (2004b) cites DOE (2002) for estimates of installed base and sales. Instead, TIAX uses more recent U.S. shipment data for 2000-2005 (from CEA 2005) to estimate the national installed base, assuming a six-year lifetime (Appliance 2005). This generally agrees with the 0.46 saturation estimate of Rosen and Meier (1999b). As California represents about 11% of the total of U.S. households (see Section 2.2.1.1), it is assumed to be home to 11% of the US installed base of compact audio systems, or 5.8 million systems. Using a similar methodology, California shipments totaled 11% of the projected 6.7 million compact audio units sold in the U.S. in 2005 (CEA 2005).

2.2.2.2. Power Draw by Mode

Fernstrom (2004b) cites DOE (2002) as the source for an estimated 9.8W standby power draw mode. Further research indicates that the value coincides with (and appears to originate from) Rosen and Meier (1999b). That study based the 9.8W average standby power draw estimate from measurements of 19 units, primarily found in retail shops. The "measurements were taken randomly; no conscious effort was taken to select a representative sample of manufacturers or quality levels." Based on the vintage of the measurements (in 1999 or earlier) and the random nature of the devices sampled, it is likely that the 9.8W value does not represent the average standby power draw of current

[10] Result appears identical to 3% discount rate due to rounding to nearest dollar.

compact audio devices. For example, Nordman and McMahon (2004) reports that standby power measurements for eight mini systems averaged 3.0W; these measurements suffer from a similar sample bias because they were the units found in the eight houses included in the study and do not take into account their market share or vintage. Furthermore, 28% of compact audio systems sold in 2004 met the EnergyStar® criterion (Fanara 2005) and most drew less than 1W in standby mode[11] (EnergyStar 2006b, CCAP 2005). EnergyStar® did not cover consumer audio products until 1999 (the requirements were announced in January), and the requirements were not revised until January, 2003 (EnergyStar 2006c). Consequently, the EnergyStar® program likely had a limited impact on the 9.8W values measured by Rosen and Meier (1999b, published in December).

Overall, the 9.8W value used by Fernstrom (2004b) appears to be much higher than that of compact audio products typically sold in 2005. Based upon a small sample of more recent measurements, a rough estimate of 3.0W is used as a re-analysis value; this estimate still has, however, a high degree of uncertainty. TIAX recommends performing targeted measurement of units that have significant market share to develop an average standby power draw value that accurately reflects the power draw of typical new units.

2.2.2.3. Annual Hours by Mode

The 6,570 hours per year in standby mode presented in Fernstrom (2004b) and obtained from DOE (2002) is very close to the estimate of Rosen and Meier (1999b). Rosen and Meier's estimate is derived by subtracting credible average per-day radio[12] and non-radio music listening data from the total number of hours in a day and then assuming that 20% of the remaining time is spent in "idle" mode and 80% in standby mode. The 20% value comes from a survey of 30 LBNL employees and the authors state that "we have little reason to believe that 20% is an accurate estimate" and note that "more reliable information was not available." Consequently, TIAX believes that the 6,570 hours per year in standby mode value has a high uncertainty. TIAX recommends further data gathering activities to develop a more accurate estimate for compact audio annual usage by mode.

2.2.2.4. Incremental Cost to Meet the Regulation

Fernstrom (2004b) estimates the incremental cost to achieve a 2W standby power draw for non-compliant compact audio products to be less than $1. The document notes that "incremental costs for most of the standby energy efficiency measures are difficult to quantify, but are expected to be very low," but provides no way to evaluate the validity of this statement. That is, the document does not provide a citation for the source of the

[11] Products launched after 1 January, 2003 must draw 1W or less in standby mode to qualify as EnergyStar® products, while products launched before 1 January, 2003 that drew 3W or less may continue to qualify for the EnergyStar® program while they remain on the market.

[12] TIAX adjusted the time spent in active mode based on an estimate that 6% of compact audio systems are used for television audio (Rosen and Meier [1999], from CEMA, 1999). For those units, the television on time was added to the listening time.

estimates, nor does it lay out the design changes or design path applied to achieve 2W (or less) standby power draw. Thus, it is not possible to assess the validity of the estimated incremental cost.

To develop meaningful incremental cost estimates, TIAX recommends performing a design option analysis for compact audio products. This involves purchasing and dissecting multiple compact audio products with different energy performance (i.e., compliant and non-compliant) produced by different manufacturers to understand what components contribute to standby power draw. Based on this analysis, it can be determined what components manufacturers may add or modify to improve energy performance and how the components impact other aspects of the design. A meaningful estimate of the incremental cost can then be developed by creating a cost model that calculates the cost impact of any design changes in a corporation's manufacturing context. The cost of compliance to the consumer can then be estimated by determining and applying typical markups associated with the product (see the discussion in Section 2.3.4).

2.2.2.5. Issues

Discussions with a manufacturer of audio equipment revealed that they are considering adding wireless connectivity/functionality to compact audio products. Based on the current definitions of compact audio products and audio standby-passive mode, it appears that this functionality would have to be provided within the 2W standby power limit. The feasibility of providing this functionality in compact audio products within the 2W requirement warrants investigation.

2.2.3. DVD Players and Recorders

Table 2-3 compares the analysis used for the original cost-effectiveness assessment, Fernstrom (2004b), with the current re-analysis values.

Table 2-3: Energy-Related Characteristics of DVD Players and Recorders

	PG&E (2004b)	Current Analysis	Comments on Data
CA Installed Base [millions]	3.1	10.6	
CA 2005 Shipments [millions]	1.6	2.4	
Avg. Lifetime [yrs]	5	5	
Standby Usage [hrs/yr]	6307	3400	High uncertainty in standby usage values; see below.
Standby Power Draw [W]	4.2	2.3	Moderate uncertainty in average power draw value for current analysis; see below.
CEC Standard Standby Power Draw [W]	3	3	
Annual Energy Savings [kWh]	7.6	0 / 4.1	No energy savings for typical new unit; up to 38% of new units sold may save some energy (rough estimate of 4.1kWh). See below.
Incremental Cost	$1	Unknown	
NPV of California Standard Over Product Lifetime [3%]	$3	Unknown	Would be roughly $1 for units that do not meet the standard (4.2W) for a $1 incremental cost
NPV of California Standard Over Product Lifetime [7%]	$3	Unknown	Would be roughly $1[13] for units that do not meet the standard (4.2W) for a $1 incremental cost
First Year GWh Savings	12	0 / 4	No energy savings for typical new unit; up to 38% of new units sold may save some energy (initial estimate of 4GWh).

2.2.3.1. Installed Base and Annual Shipments

Fernstrom (2004b) cites DOE (2002) for estimates of installed base and sales. The sales and installed base of DVD players have grown dramatically since these estimates were made (see Figure 2-1).

[13] Result appears identical to 3% discount rate due to rounding to nearest dollar.

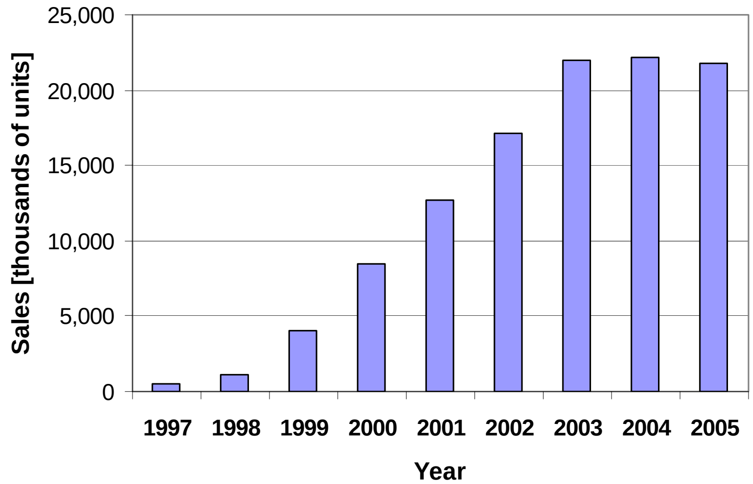

Figure 2-1: Sales of DVD Players (from CEA 2005, CCAP 2005)

The total US installed base was calculated by summing shipment data from CEA (2005) for 2001 through 2005 over the estimated five-year lifetime of DVD players and recorders (Fernstrom 2004b, Appliance 2005). Based on California's percentage of U.S. households in 2005 (11%[14]), this yields an installed base estimate of about 10.6 million DVD players and recorders in California out of the total U.S. stock of approximately 96 million units.

2.2.3.2. Power Draw by Mode

Fernstrom (2004b) cites DOE (2002) as the source for an estimated 4.2W standby power draw mode. Further research indicates that the values coincide with (and appear to originate from) Rosen and Meier (1999a). The 4.2W value reflects the average of 20 DVD players measured at LBNL, in 1999 or earlier. As shown in Figure 2-1, annual sales of DVD players have increased dramatically since then and it appears that the average standby mode power draw of current devices now is appreciably lower. For example, measurements of six DVD players in eight homes circa 2003 or 2004 have an average standby power draw value of 1.6W[15] (Nordman and McMahon 2004). Furthermore, approximately 62% of DVD players sold in 2005 were EnergyStar® units (Fanara 2005) and must draw either 1W or 3W or less in standby mode, depending on a product's launch date[16] (EnergyStar 2006b). For the 242 DVD player models listed on

[14] See the explanation in Section 2.2.1, "Televisions."
[15] These measurements were the units found in the eight houses included in the study and do not constitute a statistically-representative sample.
[16] Products launched after 1 January, 2003 must draw 1W or less in standby mode to qualify as EnergyStar® products, while products launched before 1 January, 2003 that drew 3W or less may continue to qualify for the EnergyStar® program while they remain on the market.

the EnergyStar® product list, the mean standby power draw is 1.1 W (Energy Star 2005). For perspective, the DVD player EnergyStar® requirements were announced in January, 1999, so that the EnergyStar® program likely had a very limited impact on the standby power draw measurements reported in Rosen and Meier (1999a, published in March).

Consequently, the 4.2W average DVD player standby mode power draw used in Fernstrom (2004b) is almost certainly much higher than the average standby power draw for units sold in 2005. Making the assumption that 62% of DVD products sold have an average standby power draw of 1.1 W and that the remaining 38% draw 4.2 W, the overall average standby power draw equals 2.3 W. While the assumption that 4.2W and 1.1W values represent the average standby power values for non-EnergyStar® and EnergyStar® units has some uncertainty (particularly for the non-EnergyStar® units), TIAX recommends using 2.3W. This value also is very close to the sales-weighted average standby power draw for DVD players sold by a major electronics retailer that provided sales data to TIAX for a week in December, 2005[17]. A more accurate estimate could be developed by performing measurements of units that account for a large portion of current DVD sales to develop a weighted average.

2.2.3.3. Annual Hours by Mode

Fernstrom (2004b) cites DOE (2002) as the source for the 6,307 hours per year that DVD players spend in standby mode. Further research indicates that this value is very close to the value derived from Rosen and Meier (1999a) for VCR standby mode usage. The authors of that report developed estimates for daily standby mode usage by first finding estimates for VCR active mode usage data from a *Media Dynamics* report[18] published in 1998. Since the average VCR operated in active mode for only roughly five hours per *week*, most hours were assigned to idle or off modes. Rosen and Meier were not able, however, to find data on time spent in idle or off mode and thus “were forced to provide a rough estimate based on our [their] experience" for the split in time between idle and off modes. They estimated that 75% of the remaining time the VCRs spent in standby mode, but the 75% value could not be confirmed and thus has a very high degree of uncertainty. It may well be appreciable lower. For instance, a survey of 300 UK residents in 2001 found that approximately 60% of respondents found that their VCR was left on when they arrived home from work (Harrison 2005, 2006). Although the survey has several potential sources of error, notably that it was carried out in the UK and may not reflect U.S. usage patterns, it still represents an improved estimate relative to the rough estimate of Rosen and Meier (1999a). The current re-analysis assumes that 40% of the non-operational time is spent in standby mode.

[17] Of the units sold by the retailer at that time, 9 of the 11 complied with the CEC regulation. TIAX received power draw data for 10 of the 11 units; power draw data were not provided for one non-compliant unit that accounted for approximately 5% of sales.

[18] According to Rosen and Meier (1999a), a household survey of usage in the Midwest found similar active mode usage.

To develop a more accurate estimate for DVD annual usage in idle and standby modes[19], TIAX recommends data gathering activities, e.g., demographically representative phone surveys.

2.2.3.4. Incremental Cost to Meet the Regulation

Fernstrom (2004b) estimates that the incremental cost to achieve a 3W standby power draw for non-compliant DVD players and recorders equals less than $1. The document notes that “incremental costs for most of the standby energy efficiency measures are difficult to quantify, but are expected to be very low," but provides no way to evaluate the validity of this statement. That is, the document does not provide a citation for the source of the estimates, nor does it lay out the design changes or design path applied to achieve 3W (or less) standby power draw. Thus, it is not possible to assess the validity of the estimated incremental cost.

To develop meaningful incremental cost estimates, TIAX recommends performing a design option analysis for DVD players and recorders. This involves purchasing and dissecting multiple DVD players and recorders with different energy performance (i.e., compliant and non-compliant) produced by different manufacturers to understand what components contribute to standby power draw. Based on this analysis, it can be determined what components manufacturers may add or modify to improve energy performance and how the components impact other aspects of the design. A meaningful estimate of the incremental cost can then be developed by creating a cost model that calculates the cost impact of any design changes in a corporation’s manufacturing context. The cost of compliance to the consumer can then be estimated by determining and applying typical markups associated with the product (see the discussion in Section 2.3.4).

2.2.4. Digital Television Adapters (DTAs)

Table 2-4 compares the analysis used for the CEC’s economic cost-effectiveness assessment, Fernstrom (2004b), with the current re-analysis values. A basic challenge with the analysis is that, according to the Consumer Electronics Association, no basic DTAs as defined in the California regulation were sold in the U.S. in 2005.

[19] TIAX does not expect that further refinement of active mode usage (i.e., playing or recording [for DVD recorders]) will appreciably impact the time spent in idle or standby mode because the number of active hours appears to be much smaller than both values.

Table 2-4: Energy-Related Characteristics of Digital Television Adapters (DTAs)

	PG&E (2004b)	Current Analysis	Comments on Data
CA Installed Base [millions]	0.016[20]	0	Units not available in U.S. in 2005
CA 2005 Shipments [millions]	0.016	0	Units not available in U.S. in 2005
Avg. Lifetime [yrs]	4	4	Based on set-top boxes
Active Mode Usage [hrs/yr]	2555	1470	Current analysis values from television usage; see below.
Standby Usage [hrs/yr]	6205	7290	
Active Mode Power Draw [W]	19.2	Unknown	Units not available in U.S. in 2005
Standby Power Draw [W]	8	Unknown	Units not available in U.S. in 2005
CEC Standard Active Power Draw [W]	8	8	
CEC Standard Standby Power Draw [W]	1	1	
Annual Energy Savings [kWh]	72	Unknown	Units not available in U.S. in 2005
Incremental Cost	$10	Unknown	Units not available in U.S. in 2005
NPV of California Standard Over Product Lifetime [3%]	$23[21]	Unknown	Units not available in U.S. in 2005
NPV of California Standard Over Product Lifetime [7%]	$18	Unknown	Units not available in U.S. in 2005
First Year GWh Savings	1.1	0	Units not available in U.S. in 2005

2.2.4.1. Installed Base

According to the Consumer Electronics Association, no digital television adapter products as defined in the regulations were sold in the United States in 2005.

2.2.4.2. Power Draw by Mode

DTA power draw values are not available for U.S. units because products have yet to come to market in the U.S. The baseline 8W standby and, presumably, 19.2W[22] active mode power draw values presented in Fernstrom (2004b) come from measurements of 4 British and 18 Australian set-top boxes. A market share-weighted assessment of terrestrial TV converters carried out in October, 2004 found appreciably lower values, i.e., an average power draw of 8.6W and 6.5W in active and standby modes, respectively.

[20] Assumed to equal shipments.
[21] Fernstrom (2004b) contains an apparent error, i.e., they found the $33 - $10 = $13; this is corrected in CEC (2004).
[22] Fernstrom (2004b) does not present an active mode power draw value; TIAX back-calculated it from the energy savings, "current" standby power draw, usage, and standard power draw levels presented in Fernstrom (2004b) and CEC (2004).

It is not clear how well DTA power draw characteristics for units using one digital broadcasting format will correlate with units that use another. Specifically, the U.S. will use the ATSC Digital Television Standard and Europe the DVB-T standard, which have significant differences in potential data rates[23]. Because DTAs have yet to be deployed in any appreciable quantity in the U.S., it is not yet possible to establish a meaningful baseline for their power draw, nor to assess the feasibility of the proposed standard levels. In addition, any future assessment of potential DTA standard levels will need to consider the impact of proprietary solutions that might limit the availability or increase the cost of low-power solutions.

2.2.4.3. Annual Hours by Mode

Since DTAs would be used with TVs, their usage by mode should be similar to that for TVs. Indeed, the usage estimates by mode of Fernstrom (2004b) match those used for TVs from the same report. TIAX recommends modifying that value to reflect the usage pattern for TVs presented in Section 2.2.1 (from Ostendorp et al. 2005), i.e., 1,475 and 7,285 hours per year in active and standby modes, respectively[24].

2.2.4.4. Incremental Cost to Meet the Regulation

Fernstrom (2004b) estimates the incremental cost to achieve both the 8W active mode and 1W standby power draw levels for non-compliant DTAs of less than $10. DTAs are not currently available in California, making it very challenging to develop a meaningful incremental cost to meet the standard because a baseline unit does not exist. The document notes that “incremental costs for most of the standby energy efficiency measures are difficult to quantify, but are expected to be very low," but provides no way to evaluate the validity of this statement. That is, the document does not provide a citation for the source of the estimates, nor does it lay out the design changes or design path applied to achieve the required power draw levels. Thus, it is not possible to assess the validity of the estimated incremental cost.

2.3. External Power Supplies

Table 2-5 compares the analysis used for the original cost-effectiveness assessment, Fernstrom (2004a), with the current re-analysis values.

[23] See, for example, http://en.wikipedia.org/wiki/DVB-T and ATSC (2004).

[24] This model assumes that annual hours in active mode per TV does not vary between TVs that receive TV signals through full-functionality set-top boxes and TVs that would require a DTA to convert digital terrestrial signals to analog in the future. In some instances, this may not be the case, e.g., less-used TVs in a household with multiple TVs may be more likely to not be connected to a set-top box (i.e., require a DTA in the future) and spend less time in active mode.

Table 2-5: Energy-Related Characteristics of External Power Supplies (EPSs)

	PG&E (2004a)	Current Analysis	Comments on Data
CA Installed Base [millions]	145	160	Current analysis value equals 2005 sales multiplied by the average lifetime for each product
CA 2005 Shipments [millions]	27	38	
Avg. Lifetime [yrs]	5	4.3	
Active Mode Usage [hrs/yr]	Usage by mode varies with wattage range		See Section 2.3.3 and Fernstrom (2004a)
Standby Usage [hrs/yr]			
Active Mode Efficiency [%]	Power draw varies with wattage range		See section 2.3.2
Standby Power Draw [W]			
California Standard Active Mode Efficiency [W]	Power draw varies with wattage range		
California Standard Standby Power Draw [W]			
Annual Energy Savings [kWh]	Savings vary with wattage range		High uncertainty because EPS database used has a much smaller share of switchmode EPSs than marketplace (~21% versus ~75%)
Incremental Cost – Tier 1 Standard	Varies with wattage range	Unknown	High uncertainty, particularly for units >10W; see Section 2.3.4
Incremental Cost – Tier 2 Standard			Very high uncertainty; see Section 2.3.4
NPV of California Standard Over Product Lifetime [3%]	Varies with wattage range	Unknown	Very high uncertainty; see Section 2.3.4
NPV of California Standard Over Product Lifetime [7%]			
First Year GWh Savings – Tier 1	141[25]/ 96[26]	Unknown	Very high uncertainty because EPS database used has a much smaller share of switchmode EPSs than marketplace; see Sections 2.3.4 and 2.3.5
First Year GWh Savings – Tier 2	91		

2.3.1. Installed Base

Ferstrom (2004a) developed an installed base estimate for EPSs in 2003 by extrapolating the findings of an EPS market study published in 2000 (Darnell Group 2000). A more recent version of the market study came out in 2005 (Darnell Group 2005), and TIAX used that study to develop an updated installed base estimate for California (see Table 2-6).

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[25] Revised value from Foster (2004).
[26] This value (as well as the Tier 2 value) from CEC (2004).

Table 2-6: Estimated Unit Sales of EPSs in California in 2005

Device	CA 2005 Unit Sales (millions)	Wattage Range					
		<5W	5-10W	10>-20W	>20-50W	>50-100W	>100W
Cell Phones	10.7	50%	50%		0%	0%	
Cordless Phones	4.4	75%	25%	0%			
LAN Equipment	0.14		50%	50%			
Modems	1.6		10%	40%	40%	10%	0%
PBX	0.24	10%	10%	70%	10%		
Professional 2-way Radios	0.64	0%	50%	50%			
LCD Monitor	2.9				75%	25%	
Scanners (optical)	0.44	0%	0%	50%	50%	0%	
Handheld Computers	0.56	25%	25%	25%	25%	0%	
Notebook PCs	2.0				0%	75%	25%
Portable Bar Code Readers	0.13		50%	50%	0%	0%	
Inkjet Printers / MFDs	2.3			50%	50%	0%	
Wi-Fi Access Points	0.82		45%	45%	10%		
Camcorder	0.66		50%	50%			
Digital Camera	2.4	50%	50%	0%	0%		
Portable Gaming Devices	0.36	33%	34%	33%			
Portable Audio Players	0.98	50%	50%				
Portable Video Players	1.2		33%	34%	33%		
Power Tools	2.7	30%	30%	30%	10%		
Medical	2.9	20%	25%	35%	16%	2%	2%

The estimates reflect two assumptions. First, the 2005 sales of many devices with EPSs came from the Darnell Group (2005) and 80%[27] of shipments were allocated to the U.S. U.S. sales for other products came from CEA (2005) projections. Second, the percentage of devices sold to California was assumed to scale with California's portion of the U.S. population circa 2004, i.e., 12% (U.S. Census 2006). The allocation by wattage class comes from TIAX's interpretation of qualitative information presented in Darnell Group (2005), as well as Fernstrom (2004a) for the medical segment.

Based on these values, TIAX estimates that there were approximately 160 million EPSs in service in California in 2005.

2.3.1.1. Product Lifetime

Fernstrom (2004a) uses a seven-year product lifetime to assess the economic viability of the regulations, which Foster (2004) revises to five years. Using the shipments data presented above for products using EPSs and applying typical device lifetimes from a variety of sources (primarily DOE 2005 and Appliance 2005) yields shipment-weighted

[27] Per Bryant (2006).

and energy-weighted EPS lifetime of about 4.2 and 4.3 years, respectively[28]. TIAX recommends using 4.3 years for the cost-effectiveness analyses.

2.3.2. *Power Draw by Mode*

The analysis presented in Fernstrom (2004a) relies on EPS measurements of no-load power draw and operational efficiency values at 25%, 50%, 75%, and 100% loading for 134 models[29], as well as approximately 350 units measured in a laboratory in Guangzhou, China and 47 models tested at the University of New South Wales, Australia. The EPSs measured appear to span the wattage classes considered in the analysis.

Several potential problems exist, however, with the data presented. First, it is not clear that the units measured were selected based on the applications they served and each application's portion of the overall EPS market. Second, it is not clear that the units measured were selected to represent EPSs associated with products that account for a significant portion of the market relevant to that product. If the data were not collected to represent the main applications for EPSs and the products with significant market shares for each application, then the EPS data used may not correspond to the majority of EPS products sold or in use.

Third, the measurements were made for a range of existing EPS prior to the publication of Fernstrom (2004a) in May, 2004 and their vintage is not clear. The vintage of the data would probably have an impact on the baseline efficiency and no-load power draw values collected. This occurs because the market share of switchmode EPSs continues to increase over time while that of linear supplies decreases and, as Fernstrom (2004a) correctly notes, switchmode EPSs tend to be appreciably more efficient than linear EPS. Fernstrom (2004a) estimates the market share of switchmode EPSs at 54%, citing values from a market report completed in 2000 (Darnell Group 2000). An updated version of that study, completed in 2005, estimates that switchmode supplies accounted for 75% of the North American EPS market in 2005. The same study projects that the unit-based market share of switchmode EPSs will continue to grow to 84% circa 2010 (see Figure 2-2; Darnell Group 2005). The two primary reasons they cite for the increase in switchmode EPS market share are 1) the highest growth rates are in the high-wattage applications served primarily by switchmode supplies and 2) the cost of switchmode supplies continues to decrease due to higher production volumes (Darnell 2005).

[28] The implicit assumption is that EPS lifetime equals the lifetime of the products using the EPS.
[29] The report notes 197 efficiency conditions measured, reflecting several EPSs that can generate multiple output voltages (only one at a time).

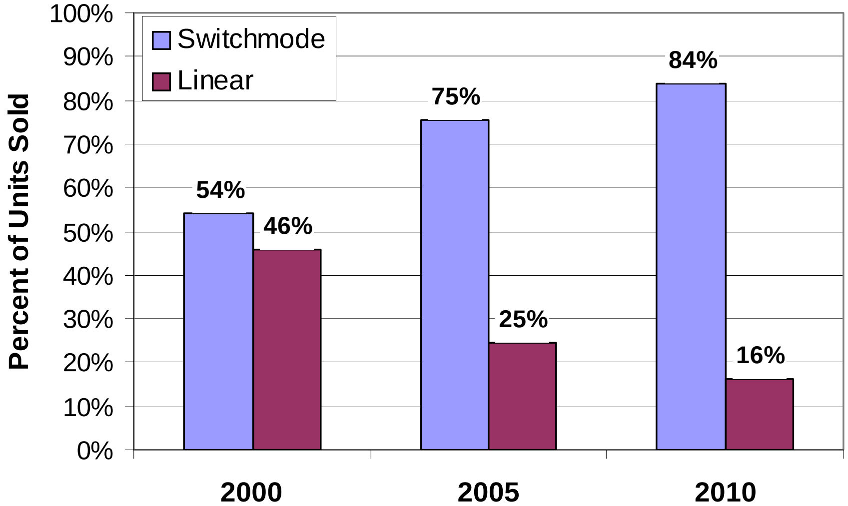

Figure 2-2: External Power Supplies – Percentage of Units Sold in North America by Design Type (based on Darnell Group 2005, Darnell Group 2000 [from Fernstrom 2004a])

In terms of the energy savings analysis, a 40% decrease in the market share of linear EPSs has two potential impacts. First, it likely increases the percentage of EPSs that meet the Tier 1 and Tier 2 standards. In that case, the standard would result in no energy savings for a larger portion of EPSs than before. Second, the greater switchmode EPS market share likely decreases the energy savings from the Tier 1 and Tier 2 standards for non-compliant EPSs because many of the EPSs that do not meet either standard will be switchmode EPSs that replaced (typically) less-efficient linear EPSs.

TIAX did not have the opportunity to measure the performance characteristics of a statistically significant sample of EPSs that mirrored the EPS market. For a preliminary analysis, TIAX assessed a database (EfficientPowerSupplies.com 2006) developed by Ecos Consulting, the lead consultant on the Fernstrom (2004a) study. It is possible – but not certain – that many of the measurements appearing in that website were used for the Fernstrom (2004a) EPS assessment. The measurements reported in the database appear to primarily have been made in 2003 and, thus, do not fully represent the current penetration of switchmode power supplies. A review of the database identifies the power supply type for around 150 EPSs and about 70% of the EPSs are linear EPSs, i.e., the distribution of EPSs in the database is roughly the inverse of the current market reality (~75% switchmode EPSs).

In sum, if the Fernstrom (2004a) analysis primarily relies upon EPS measurements from – or similar to – the EfficientPowerSupplies.com database and/or did not use a sample of EPSs with a distribution of regulation type that is similar to that of the actual EPS market, it provides a misleading view of the energy performance of recent and new EPSs in the U.S. market. It appears that this is the case. Data presented in Fernstrom (2004a) indicate that the mathematical average of EPS efficiencies measured at 25%, 50%, 75%, and 100% of full load are generally similar to the average values weighted by usage and efficiency as a function of loading (see Figure 2-3). The mathematical average values for EPSs efficiency reported at EfficienctPowerSupplies.com also are generally similar to those reported in Fernstrom (2004a).

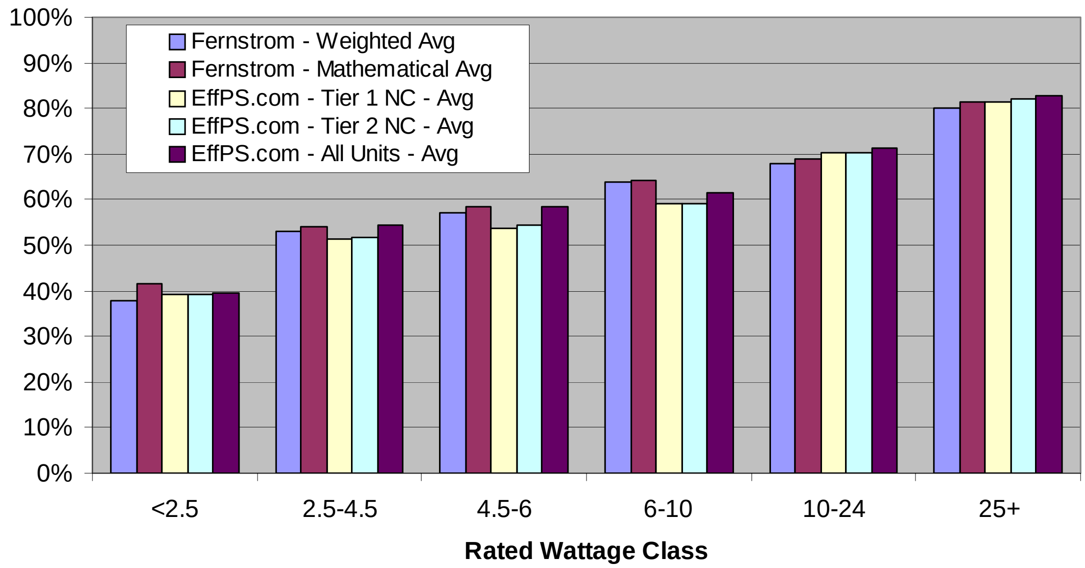

Figure 2-3: Comparison of EPS Efficiency Values (NC=Non-Compliant; from Fernstrom 2004a and EfficientPowerSupplies.com 2006)

Consequently, the EPS energy consumption and savings values presented in Fernstrom (2004b) are almost certainly higher than the market reality because the dataset used appears to significantly over-sample linear EPSs relative to swtichmode EPSs, particularly in the lower wattage class where switchmode power supplies have gained significant market share since 2000. As noted in the prior section, the Darnell Group (2005) projects that the market share of switchmode EPSs is projected to continue to grow from 2005 to 2010, which will likely increase the efficiency of "typical new" EPSs sold in the future. This would further depress energy savings from the standard in the future

2.3.3. Annual Hours by Mode

Fernstrom (2004a) presents average usage patterns for different EPS wattage categories based on usage estimates for several devices using EPSs, taking into account their installed base. The re-analysis also uses these values.

It is important to note, however, that the average usage patterns likely mask large variations in actual average usage by mode for different product types. For example, a 5W EPS for a cordless phone will spend almost all of its time at some portion of its rated load and very little – if any – time unplugged or at no-load (i.e., EPS plugged in and disconnected from the phone's base station). On the other hand, a 5W digital camera EPS may typically spend most of its time unplugged. In those two instances, the energy savings achieved by the standard for non-compliant EPSs would vary greatly, as would the cost-effectiveness. Because Fernstrom (2004a) analyzes EPSs based on wattage categories instead of applications, it does not reveal the product categories for which the standard will likely result in significant energy savings, as well as positive and negative cost-effectiveness. Separate product-by-product analyses would be more important if incremental costs to meet the standard also show significant variation by product type, as this non-linear relationship could produce different results than the (implied) assumption that EPS incremental cost only varies with wattage class and the standard level.

2.3.4. Incremental Cost to Meet the Regulation

Fernstrom (2004a) presents estimated incremental costs for non-compliant devices to meet the standard (see Table 2-7).

Table 2-7: Incremental Cost Estimates for EPS Standard Levels in Fernstrom (2004b)

Wattage class	Tier 1	Tier 2
<2.5	$0.30	$0.45
2.5 to <4.5	$0.30	$0.45
4.5 to <6	$0.40	$0.60
6 to <10	$0.45	$0.75
10 to <24	$0.63	$0.98
24+	$0.80	$1.30

The lead analyst of the Darnell Group (2005) study estimates that the average incremental OEM cost of switchmode EPSs relative to linear EPSs equals 18% and 17% in the <5W and 5-10W categories, respectively. This translates into an incremental cost of approximately $0.23 for the <2.5W and 2.5-4.5 wattage class, $0.30 for the 4.5-6W range, and $0.38 for the 6-10W range. Overall, the values presented in Fernstrom (2004a) for the wattage classes above generally seem to correlate with the OEM costs developed from Darnell (2005) to replace a linear EPS with a switchmode EPS.

On the other hand, changing to a switchmode supply is often not sufficient to meet the Tier 1 or Tier 2 requirements and additional costs accrue to improve EPS performance to meet the standard. Data from EfficientPowerSupplies.com (2006) indicate that about 65% and 80% of switchmode EPSs did not meet the Tier 1 and Tier 2 standards, respectively, and those units will likely have to incur additional cost to meet the required performance levels. Furthermore, the actual cost to the consumer for consumer electronics incorporates at least three markups that need to be considered, including factory-to-retailer, M_{rf}, retailer-to-consumer, M_{rc}, and state taxes, M_{tax}. The incremental cost to the consumer, $dCost_c$, equals the product of these three markups and the incremental OEM cost (for outsourced EPSs) or production cost (for EPSs produced in-house), $dCost_{OEM}$:

$$dCost_c = dCost_{OEM} \times \left(M_{rf} \times M_{rc} \times M_{tax} \right).$$

These do not appear to be included in the Fernstrom (2004a) estimates; if they are, then the incremental cost values presented for the four aforementioned wattage classes appear to be very low.

In practice, factory-to-retailer cost and retailer-to-consumer cost markups for different consumer electronic products vary significantly with product type and niche, as well as with manufacturer market share, manufacturing location, product maturity, and retailer / sales channel. Consequently, TIAX recommends that future cost-effectiveness assessments include a more detailed study of these markups for key products that use EPSs (e.g., cell phones, cordless phones, LCD monitors, notebook PCs). Table 2-8 presents an initial set of markups for consumer electronics, based upon a study of the cost impact of digital TV tuners on TVs. The study interviewed major TV manufacturers and retailers to develop two sets of markup factors, one for low-end “leader” models and another for high-end receivers. Subsequently, they applied these markups to a television component, a digital television receiver, to estimate the incremental cost to the television (ADL 2001). The current analysis uses the same markups and, using the same methodology, applies them to EPSs used with consumer electronics to develop a range of incremental costs to the consumer.

Table 2-8: Sample Markups for Televisions (from ADL 2001)

Markup	High	Low
Factory-to-retailer	2.5	1.5
Retailer-to-consumer	1.35	1.2
CA Tax	1.0775[30]	
TOTAL	3.64	1.94

Table 2-9 presents cost-effectiveness results for the four wattage classes with incremental cost estimates developed from the Darnell Group (2005) data. The preliminary energy savings and cost-effectiveness estimates shown are based on data for non-compliant units from the EfficientPowerSupplies.com data set using the usage patterns from Fernstrom (2004a). It is important to recall that the per-unit energy savings presented are almost certainly high because the EPS data used for the analysis has a much higher percentage of linear EPSs than is typical of typical new EPSs (per Darnell Group 2005). Moreover, the incremental costs used are likely low because the Darnell Group (2005) incremental cost estimates only appear to account for the cost to change from a linear to a switchmode EPS. As discussed earlier, many switchmode EPSs appear not to satisfy the standard and will thus require additional cost to improve their energy performance and satisfy the standard.

Table 2-9: Initial Re-Analysis of EPS NPV for Tier 1 Standard – Ranges for Low and High Markup Cases

Wattage Class	Incremental Cost [$/unit]	Savings NPV - 3%	Savings NPV - 7%	Total NPV – 3% [$]	Total NPV – 7% [$]
<2.5	$0.44* – 0.83*	$0.91	$0.79	$0.47* – 0.09*	$0.35* - (0.04)*
2.5 to <4.5	$0.44* – 0.83*	$1.56	$1.35	$1.12* - 0.73*	$0.91* - 0.52*
4.5 to <6	$0.59* – 1.10*	$1.85	$1.60	$1.26* – 0.75*	$1.01* - 0.50*
6 to <10	$0.73* – 1.37*	$2.57	$2.22	$1.84* – 1.20*	$1.49* - 0.85*
10 to <24**	$1.22- 2.29	$1.22	$1.05	$(0.01)-(1.07)	$(0.17)-(1.24)
24+**	$1.55 - 2.91	$1.37	$1.18	$(0.18)-(1.54)	$(0.37)-(1.73)

*High uncertainty, only includes approximate incremental cost to go from linear to switchmode EPS, not to meet standard; see discussion
**Very high uncertainty for 10+ wattage classes, based on markup of Fernstrom (2004a) values; see discussion
Note: Values in parentheses are negative values.

[30] CEC (2004) used a California state tax rate of 7.75%.

Table 2-10: Energy Characteristics of the Non-Compliant EPSs (Tier 1) Used for the Preliminary Re-Analysis (data from EfficientPowerSupplies.com)

Wattage Class	Average Efficiency	Average Standard Efficiency	Average No-Load Power Draw [W]	Average Standard No-Load Power Draw [W]	Average Rated Power [W]	Annual Unit Energy Savings [kWh]
<2.5	39%	48%	0.84	0.50	1.6	1.9
2.5 to <4.5	51%	60%	0.99	0.50	3.3	3.2
4.5 to <6	54%	63%	1.1	0.50	4.9	3.8
6 to <10	59%	67%	1.1	0.50	6.9	5.3
10 to <24	70%	73%	1.1	0.75	14	2.5
24+	81%	82%	2.0	0.75	46	2.8

The cost-effectiveness values for the 10+ wattage class for the Tier 1 standard have a very high uncertainty as independent cost data for this range were not found. According to Darnell Group (2005), EPSs in the 10+ wattage classes overwhelmingly use switchmode supplies[31]. In this regime, the incremental cost relationship from Darnell Group (2005) loses its validity and the incremental cost depends to a greater extent on the use of more efficient switchmode EPSs. Similarly, sufficiently detailed data to derive incremental cost estimates were not available to develop incremental cost values to meet the Tier 2 standards for all wattage ranges.

All three sources used to develop the incremental cost estimates presented in Fernstrom (2004a) have significant shortcomings that compromise their accuracy. The first source cited by Fernstrom (2004a) to support the incremental cost estimates is a personal communication from two employees of an EPS manufacturer (Nolan and Archer of Celetron). Although this may be a useful check for incremental costs, information derived from a single manufacturer has limited value and can be skewed by several different factors, including manufacturing volumes, markets served, and company technology preferences. The approach of basing costs on discussions with manufacturers without performing technical cost modeling to confirm the findings can have significant shortcomings and inaccuracies. Furthermore, the incremental percentage cost range

[31] TIAX calculations estimate the percentage of linear EPSs to be between 10 and 15 percent in these ranges.

attributed to Nolan and Archer (2002)[32] are approximately half of that cited in an earlier report (Calwell and Reeder 2002) that forms the basis of much of Fernstrom (2004a)[33]. The reason for these changes is not clear.

The second source cited for the incremental cost estimates is "a leading manufacture [sic] of switch mode power supply integrated circuits[34]" (Fernstrom 2004a). Many of the incremental cost values to meet the Tier 1 standard fall within the range of incremental costs they reported. Although these values may be credible estimates, they warrant thorough evaluation to ensure their validity, i.e., by performing technical cost modeling. Fernstrom (2004a) presents no evidence that the authors of that study carried out an independent evaluation.

The third source for the incremental cost estimates is an anecdotal comparison of a linear and a switchmode power supply with similar characteristics sold by the same electronics supplier[35]. Although TIAX agrees that switchmode power supplies can, in some cases, have a similar or lower cost than an equivalent linear power supply, quote-based (especially single-point) comparisons can prove very misleading due to differences in manufacturing volumes, purchasing volumes, purchasing negotiations, etc. Fernstrom (2004a) acknowledges these challenges, stating that "Pricing information for individual unit purchases of individual models can often be obtained in the marketplace, but obtaining firm, large volume quotes from manufacturers of competing technologies is difficult." In addition, as shown earlier, many switchmode EPSs do not meet the Tier 1 and/or Tier 2 standards, i.e., simply changing to a switchmode EPS would not always ensure compliance and a more efficient (and often more costly) switchmode EPS would be needed to meet the standard.

Based on prior support for DOE Energy Efficiency Rulemakings, TIAX believes that the most effective way to develop meaningful incremental cost values is to perform a bottom-up manufacturing cost analysis for comparable units designed for the same application. Ideally, analyses would be performed for multiple key product categories that each account for a significant portion of EPS energy consumption and unit

[32] Cited in both cases as "Personal Communication, Steve Nolan and Michael Archer, Celetron, March, 2002."
[33] Fernstrom (2004a) attributes to Nolan and Archer (2002): "After interviewing a number of manufacturers of highly efficient power supplies, we believe the incremental costs are between 8 and 15% for most models, decreasing as wattage increases." In contrast, Calwell and Reeder (2002) cite Nolan and Archer (2002) for: "After interviewing a number of manufacturers of highly efficient power supplies, we believe the incremental costs are about 30% for power supplies up to 10W output, about 20% for units in the 10 to 20 watt range, and 10% or less for somewhat higher wattage models."
[34] Attributed to Balakrishnan and Walker, Power Integrations, in Fernstrom (2004a).
[35] A Google search shows that Hosfelt Electronics is a "Supplier of surplus, new, industrial and educational electronics."

shipments. This involves purchasing multiple units of varying efficiency made by at least two manufacturers[36] and performing hardware teardowns on the units. From these teardowns, a bill of material (BOM) is developed, the manufacturing processes understood, and an independent cost estimate generated for each unit. Such modeling enables development of cost estimates for different design options and pathways used to attain energy performance levels independent of production volume and purchasing power. It involves assessment of several factors (see Table 2-11).

Table 2-11: Typical Manufacturing Cost Model Components (based on DOE 2004)

Corporate	• Research and Development • Net Profit • General & Administration • Warranty • Taxes • Sales and Marketing
Fixed	• Equipment and Plant Depreciation • Tooling Amortization • Equipment Maintenance • Utilities • Indirect Labor • Cost of capital • Overhead Labor
Variable	• Manufactured Materials • Purchased Materials • Fabrication Labor • Assembly Labor • Shipping • Indirect Materials

It does not appear that an engineering-based bottom-up cost assessment for key products that use EPS was performed in support of any of the incremental cost estimates presented.

In sum, TIAX believes that an approach that relies on vendor quotations for units or raw data provided from EPS manufacturers will probably not provide an accurate assessment of the incremental cost to meet the CEC Tier 1 and Tier 2 standards. In turn, this precludes a meaningful cost-effectiveness assessment and arriving at a conclusion that the Tier 1 and Tier 2 EPS standards are cost-effective or are not cost-effective. TIAX believes that an engineering cost model-based evaluation of incremental cost is needed to

[36] Analyzing products made by different manufacturers is important to understand the different strategies/pathways used to achieve energy efficiency.

generate accurate and defensible incremental cost estimates and cost-effectiveness values for EPSs by greatly reducing the impact of manufacturing volumes, purchasing volumes, purchasing negotiations, sourcing, and company practices on costs.

2.3.4.1. Future Cost Trends

The incremental cost of switchmode EPSs relative to linear EPSs has decreased over time and, in some cases, is now less than that of linear EPSs. An EPS market study projects that the cost of switchmode supplies will continue to decrease due to higher production volumes (Darnell Group 2005), as well as decreases in the price of silicon (the main ingredient of switchmode power supplies). In contrast, the price of linear EPSs will probably not decrease as rapidly because many manufacturers' costs are very close to their production costs (Darnell Group 2005) and the prices of copper and steel, the main materials used in linear supplies, have increased significantly over the past few years[37].

2.3.5. California Energy Savings Potential

Tables 2-12 and 2-13 summarize the preliminary re-analysis of annual energy savings estimates for the Tier 1 and Tier 2 EPSs in California.

Table 2-12: Initial Re-Analysis of EPS NPV for Tier 1 Standard Using EfficientPowerSupplies.com Dataset

Wattage Class	Number of Annual CA Unit Sales [Millions]	% Non-Compliant Units	# Non-Compliant Units, Annual CA Sales [millions]	First Year Energy Savings [GWh]
<5	12.0	84%*	10.1*	26**
5-10	11.7	84%*	9.8*	49**
>10-20	5.8	84%*	4.9*	12**
>20-50	5.5	84%*	4.7*	12**
>50-100	2.5	84%*	2.1*	5.8**
100+	0.6	84%*	0.5*	1.3**
TOTALS	39	84%*	32*	107**

*High uncertainty due to much higher share of switchmode EPSs in marketplace (~75%) than in EPS database used (~21%).
**Very high uncertainty (same reason)

[37] See, for example, Bureau of Labor Statistics (2006) producer price indices for commodities at: http://data.bls.gov/cgi-bin/surveymost for "metals and metal products" and "iron and steel."

Table 2-13: Initial Re-Analysis of EPS NPV for Tier 2 Standard Using EfficientPowerSupplies.com Dataset

Wattage Class	Number of Annual CA Unit Sales [Millions]	% Non-Compliant Units	# Non-Compliant Units, Annual CA Sales [millions]	First Year Energy Savings [GWh]
<5	12.0	88%*	10.6*	28**
5-10	11.7	88%*	10.3*	56**
>10-20	5.8	88%*	5.1*	19**
>20-50	5.5	88%*	4.9*	19**
>50-100	2.5	88%*	2.2*	8.7**
100+	0.6	88%*	0.5*	2.0**
TOTALS	39	88%*	34*	132**

*High uncertainty due to much higher share of switchmode EPSs in marketplace (~75%) than in EPS database used (~21%).
**Very high uncertainty (same reason)

The dataset used for the preliminary energy-savings has a much higher portion of linear EPSs than the 2005 market (~75% versus ~25% market share). Although a significant percentage of switchmode EPSs do not appear to meet the Tier 1 or Tier 2 standard, the increased market share of swithcmode EPSs likely increases the percentage of EPSs that meet the Tier 1 and Tier 2 standards. In that case, the standard would result in no energy savings for a larger portion of EPSs than before. In addition, the market shift to switchmode EPSs also decreases the difference in energy performance between the average non-compliant and compliant EPS. Finally, the approach taken in Fernstrom (2004a) to calculate energy savings also tends to over-estimate energy savings from the standard because it calculates energy savings “not on the basis of barely meeting the proposed standards levels, but on the average efficiency difference between the average compliant product and the average non-compliant product already measured.” EPSs need only meet the standard, not exceed it.

It is difficult to accurately quantify these impacts because the limited sample size of switchmode EPS data available in the different wattage ranges precludes a meaningful comparison between average linear and switchmode EPS efficiency and no-load power draw in the different ranges. Based on an initial review of the data, however, it would not be surprising if these effects resulted in large (e.g., on the order of 50%) reduction in energy savings relative to the calculated values. The percentage reduction in energy savings relative to the calculated values will likely increase in the future as switchmode EPSs continue to gain market share.

To better quantify the actual energy savings from the EPS standards, a much more representative data set of EPS performance needs to developed that accurately reflects the breakdown of EPSs sold by application and by EPS architecture (i.e., switchmode versus linear).

2.3.6. Other Issues

2.3.6.1.1. Test Procedure – 115V and 230V Testing

Most external power supplies for portable devices are "universal" in that they are capable of operating from an AC voltage between 100V and 240V. In order to accommodate such a wide voltage range, the input stage needs to be designed for both the highest voltage and highest current (which is seen at the lowest voltage). If constant efficiency is desired across the voltage range, then the input stage of the EPS needs to be oversized by a factor of approximately two (2), which increases unit cost. If, however, the power supply is designed to be used at a specific voltage, i.e., 120V in North America or 240V in Europe, then the designer can optimize EPS performance and cost for that particular operating point. In that case, the EPS still functions as a universal supply, but will perform less efficiently at alternative input voltages. Testing at higher input voltages also tends to increase no-load power losses because higher voltages increase switching losses and core losses in all modes. Protective elements (e.g., varistors) placed across the input of the EPS also tend consume more power at higher voltage. Consequently, the requirement of the CEC regulations that EPSs must meet energy-performance requirements at both the 115 V and 230V test conditions, instead of only the ~115-120V power used in California, increases the cost impact of complying with the standard.

2.3.6.2. Efficiency for EPSs with Lower DC Output Voltages

Concerns have been raised that EPS efficiency tends to decrease as the DC output voltage decreases. Figure 2-4 shows the result of units included in a power supply survey[38] and illustrates this trend.

[38] Only units clearly identified as linear or switchmode EPSs were included in the data presented.

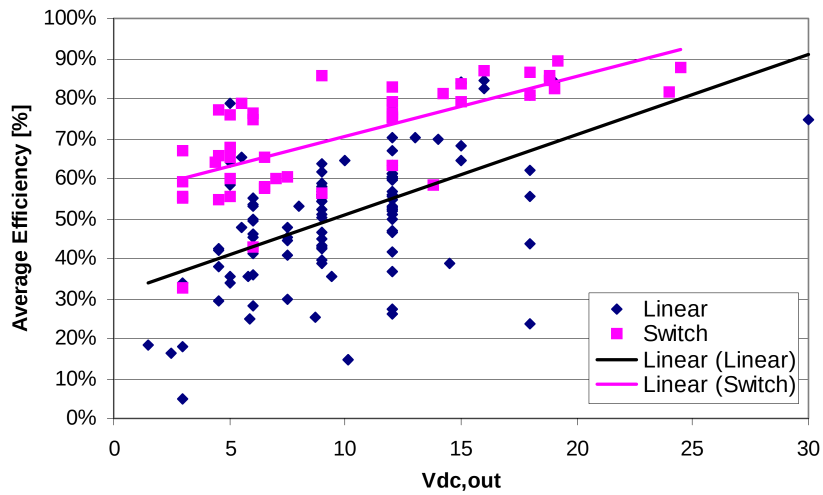

Figure 2-4: EPS Average Efficiency versus DC Output Voltage (data from EfficientPowerSupplies.com)

Rectifying diodes are responsible for a large portion of losses in EPSs with low output voltages. Since the voltage across the diodes is essentially constant (approximately 0.4V) and in series with the output, its impact can be significant at low output voltage. Synchronous output rectifiers address this problem by placing active switches in parallel with the diodes. Whenever the diode conducts, the switch closes and provides a low loss path for the current. This technique is well established for computer power supplies and other applications, such as Power over Ethernet (PoE). Implementing active rectification adds an additional, likely moderate, incremental cost.

In addition, no-load power draw tends to increase with output wattage, as the EPS uses a larger switch, causing the control circuitry to consume more energy.

2.3.6.3. Surge Immunity

In certain cases, products using EPSs may have special requirements that impact EPS design. TIAX learned from industry interviews that the performance of switchmode power supplies with respect to voltage spikes on the utility-lines is a major concern. This issue is of particular importance to the makers of cordless phones because portable phones are more vulnerable to line surges since they are connected both to the grid and the telephone lines. A major cordless phone manufacturer indicated that they had experienced high phone return rates after thunderstorms and invested a significant amount of effort to solve this problem in the current linear EPSs. Changing from linear to switchmode power supplies would require a complete new design and validation effort and could result in decreased consumer utility and higher return rates if the failure rate of phones during thunderstorms increases.

IEC 61000-4-5 is the global standard for voltage and current test conditions for equipment connected to the AC mains. The standard specifies surge waveforms for different equipment installation classes, up to 4 kV. Cordless phone manufacturers have indicated that their internal requirement tolerance of up to 8 – 10 kV without equipment damage. While this goal had been achieved with linear supplies, it appears to be more challenging to attain with switchmode designs.

Using a resettable fuse with a surge suppressor, such as a metal oxide varistor, could very effectively protect switchmode supplies from voltage spikes while having only a minimal impact on cost and efficiency. The concern, however, is that not only the power supply survive the surge, but that the cordless phone be unharmed as well. This appears to be a non-trivial issue, especially due to the high-frequency grounding loop between the AC mains and telephone line created by intentional or parasitic capacitance. A common practice for reducing the electromagnetic interference (EMI) of switchmode supplies is to place a safety-rated capacitor (Y-cap) across the isolation transformer. This capacitor creates a more direct high-frequency link than exists in linear supplies and will require mitigating techniques in the cordless phone base unit that incur additional costs. The magnitude of those costs was not assessed in this study.

3. Conclusions and Recommendations

TIAX has performed an assessment of the cost-effectiveness analyses used to support the California energy efficiency regulations promulgated for televisions, DVD players and recorders, compact audio products, digital television adapters (DTAs), and external power supplies (EPSs). This section summarizes the key findings of the assessment and recommendations based on the findings.

3.1. Conclusions

The key findings of the study are organized by device type. In all cases, the studies cited by the CEC in the development of the standards are referred to as "the original analysis," while TIAX's analysis is referred to as the "re-analysis."

3.1.1. Consumer Electronics – Televisions, Compact Audio Products, DVD Players & Recorders, Digital Television Adapters

Most of the original analyses use outdated power draw values to develop an energy-consumption baseline that, in many cases, does not appear to reflect the performance of typical new devices. Furthermore, the validity of the incremental cost estimates for non-compliant televisions, DVD players and recorders, compact audio products and DTAs cannot be assessed because the original analyses do not provide citations for the source of the estimates, nor do they lay out the design changes or design path applied to meet the standard. This basic flaw precludes meaningful cost-effectiveness assessments for these products, i.e., it is not possible to conclude that the standards are either cost-effective or not cost-effective.

Televisions: The original analysis relied on older power draw data that does not represent typical new products. A more comprehensive and recent data set yields a lower value (3.9W versus 7.3W) that decreases the first-year energy savings by about 70%, from 68GWh to 21GWh. In addition, no source or explanation is provided for the $3 incremental cost for a typical new non-compliant unit to meet the standard, nor is a design path outlined to achieve the savings that would enable assessment of incremental cost estimate. Consequently, TIAX believes that an accurate and verifiable incremental cost to achieve the standard for non-compliant units is not yet known and, therefore, a conclusion that the television standby power standard is cost-effective is premature.

Compact Audio: The original analysis relied on a limited sample (19 units) of measurements from 1999 or earlier that do not appear to represent the standby power draw characteristics of typical new compact audio products. Notably, the EnergyStar® program for compact audio products came into existence in 1999 and accounted for 28% of units sold in 2004. Most EnergyStar® units consumed less than 1W in standby mode compared to the 9.8W average used in the original database. Although it has significant uncertainty, an initial best-estimate of 3W average standby power draw decreases the estimated first year energy savings by about a factor of ten, from 56GWh to 5GWh. The savings estimates also have further uncertainty because they rely upon a usage estimate developed from a statistically non-significant survey (30 people at LBNL). Furthermore, no source or explanation is provided for the estimated $1 incremental cost for a typical new non-compliant unit to meet the 2W standby power standard, nor is a design path outlined to achieve the savings that would enable assessment of the incremental cost estimate. Consequently, TIAX believes that the incremental cost to achieve the standard for non-compliant units is not yet known. This and the high uncertainty in the per-unit energy savings of the standard, precludes a conclusion that the compact audio product standards are cost-effective or are not cost-effective.

DVD Players and Recorders: The original analysis relied on several dated or potentially flawed assumptions that bring into question the projected energy savings and cost-effectiveness of the standard.

- *Standby Power Draw* –The original analysis uses values measured in 1999 or earlier for a limited number of units (20). Since 1999, the installed base of DVD players and recorders has increased approximately 15-fold. Furthermore, about 62% of units sold in 2004 were EnergyStar®-compliant units that draw an average of about 1W as compared to the 4.2W level used for the original analysis. Thus, the standard will not achieve any energy savings for the majority of DVD players and recorders sold.
- *Annual Hours in Standby Mode* – The original analysis uses a rough assumption developed without data. A survey conducted since then suggests that the annual hours may be overestimated by approximately a factor of two.
- *Energy Savings* – Based upon the re-analysis of standby power draw and annual hours in standby mode values, TIAX estimates that the standard will realize approximately 1/3rd of the projected first-year savings, or 4GWh[39].
- *Incremental Cost* – No source or explanation is provided for the $1 incremental cost estimate, nor is a design path outlined to achieve the savings that would enable assessment of the incremental cost estimate. Consequently, TIAX believes that the incremental cost to achieve the standard for non-compliant units is not yet known. This precludes a meaningful cost-effectiveness assessment and questions the CEC conclusion that the standards are cost-effective.

[39] A more precipitous decrease in energy savings does not occur because the annual sales of DVD players and recorders in California increased by more than 50%.

Digital Television Adapters (DTAs): The original analysis developed baseline energy characteristics and recommended standards levels for these products, but the DTAs covered in the regulations have yet to come to market in the U.S. Consequently, the energy performance characteristics of the baseline units are not known and it is not possible to accurately assess their energy consumption, the incremental cost to comply with the active and standby mode power draw standards, and the cost-effectiveness of the proposed regulations.

3.1.2. External Power Supplies (EPSs)

The original external power supply (EPS) analysis appears to rely on a data set that is not representative of EPS characteristics in 2005. Specifically, the efficiency characteristics of the data used for the original analysis correlate closely with an on-line dataset analyzed by TIAX that is populated overwhelmingly (~70%) by less-efficient linear EPSs. In fact, linear EPSs actually only accounted for 25% of units sold in 2005. Consequently, the original analysis likely significantly overestimates the energy savings of both the Tier 1 and Tier 2 standards. The limited number of switchmode EPS efficiency measurements in the database precluded a meaningful qualitative assessment of the magnitude of the overestimate in the re-analysis.

The incremental cost estimates used in the original analysis to assess the cost-effectiveness of the EPS standard levels also have large uncertainties. They rely on estimated incremental cost and cost percentages from selected manufacturers and quotes for EPSs obtained from an electronics supplier. TIAX believes that all of these sources potentially have serious flaws that tend to bias the cost information provided, such as differences in manufacturing volumes, sales volumes, purchasing volumes, purchasing negotiations, etc., and complicate the development of meaningful cost comparisons. Technical cost modeling can greatly reduce the impact of these biases to develop realistic incremental cost estimates, but it appears that the original analysis did not carry out such modeling. A comparison of the original incremental costs with the cost difference between comparable switchmode and linear EPSs smaller than 10W (derived from a market report) suggests that the original incremental costs may be comparable with actual incremental OEM costs *without taking into account markups*. A preliminary assessment suggests actual markups between 1.9 and 3.6. In addition, most of the switchmode EPSs included in the EPS database did not meet the Tier 1 or Tier 2 standard, indicating that additional modifications – at additional cost – are required to meet the standard.

Finally, the cost-effectiveness of the standards relies upon aggregate usage values for different wattage classes. In practice, the average usage by mode for different product types varies significantly, e.g., between cordless phones and camcorders. In those two instances, the energy savings achieved by the standard for non-compliant EPSs would vary greatly, as would the cost-effectiveness. Separate product-by-product analyses would be more important if incremental costs to meet the standard also show significant variation by product type. A non-linear relationship could produce different results than the (implied) assumption that EPS incremental cost only varies with wattage class and the standard level.

In sum, TIAX believes that the problems outlined with the EPS energy performance and cost data preclude arriving at a conclusion that the Tier 1 and Tier 2 standards are cost-effective or are not cost-effective.

3.2. Recommendations

These conclusions highlight several problems with crucial assumptions in the original analyses that need to be addressed to determine if the standards are cost-effective or not cost-effective. TIAX recommends the following activities to provide quality information to assess the economic viability of the standards.

Incremental Costs - To generate accurate and defensible incremental cost estimates and cost-effectiveness values independent of confounding factors, such as manufacturing volumes, purchasing volumes, purchasing negotiations, sourcing, pricing, and company practices, TIAX recommends performing design option analysis for all products considered in this analysis, with the exception of DTAs (because baseline units do not yet exist). This involves purchasing and dissecting multiple products with different energy performance (i.e., compliant and non-compliant) produced by different manufacturers to understand what components contribute to standby power draw. Based on this analysis, it can be determined what components manufacturers may add or modify to improve energy performance and how the components impact other aspects of the design (and, for EPSs, any impacts on the cost and performance on the device powered by the EPS). A meaningful estimate of the incremental cost can then be developed by creating a cost model that calculates the cost impact of any design changes in a corporation's manufacturing context. The cost of compliance to the consumer can then be estimated by applying typical markups associated with the product, another area warranting further evaluation. Specifically for EPS, the EPSs selected should come from the product categories and applications that account for significant portions of EPS energy consumption and devices that have significant market share.

Measurements of Power Draw Characteristics – Two categories, compact audio products and EPSs, have notably large uncertainties in the energy performance of typical new products, i.e., standby power draw for compact audio and no-load and efficiency measurements for EPSs. A solid set of baseline measurements is needed for representative measurement samples. For compact audio products, TIAX recommends performing targeted measurement of an appreciable quantity of units that account for a majority of current sales to develop an average standby power draw value that accurately reflects the power draw of typical new units on the market. The current EPS baseline suffers from an apparent significant over-sampling of linear EPSs relative to more efficient switchmode EPSs, despite the market dominance of switchmode devices. In addition, the units measured do not appear to be weighted by application (either for existing units or energy consumption). For EPSs, TIAX recommends measurements of currently for-sale units in each of the desired wattage classes to develop a statistically significant estimate for baseline energy performance in each wattage class. The EPSs selected should be associated with the product types that account for significant portions of EPS energy consumption in each wattage class and come from products that account for a significant portion of each product's market share.

Usage Patterns: For DVD players and recorders and compact audio products, TIAX recommends data gathering activities, such as demographically representative and statistically significant phone surveys or end-metering activities, to develop more accurate estimate for the annual usage of these products in idle and standby modes. Depending on the results of the EPS manufacturing analysis, TIAX would recommend developing improved usage pattern data by application if the incremental cost to meet the EPS standards varies appreciably with product type.

Discount Rate: TIAX recommends using a 7% real discount rate, a rate typically used in DOE appliance rulemaking analyses, instead of the 3% real discount rate used in the original analyses.

EPS Test Procedure: The EPS test procedure calls for evaluating energy performance at both 115V and 230V AC inputs, but only 115V power is used in California. This requirement inhibits the development of designs optimized to perform at 115V and increases the cost of complying with the standard. Because only ~115V power used is in California and, consequently, EPS performance at 230V is not relevant to EPS energy performance in California, TIAX recommends eliminating this testing requirement.

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